# Mission Highlights STS-79

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## STS-79 combines double Spacehab and Mir docking

The addition of Russian Space Station Mir logistics and experiments to shuttle based experiments necessitated the creation of the first double Spacehab module. The double Spacehab, a module created by literally putting two single Spacehab modules together, provided a versatile pressurized volume similar in size to the more familiar Spacelab. Throughout the flight, the STS-79 crew worked with logistics preparations and on a number of experiments in the double Spacehab module. Among them were the Active Rack Isolation System, a prototype of a ISS system designed to dampen the effects of crew movements and thruster firings on sensitive experiments. STS-79 also worked with the Mechanics of Granular Materials experiment, which is designed to help scientists and civil engineers understand the behavior and stability of granular materials. The Extreme Temperature Translation Furnace studied the influence of microgravity on liquid phase sintering of metals at 900 degrees Celsius. The experiment could lead to the development of purer alloys.

Among equipment transferred to Mir were three experiments, the Biotechnology System, the Material in Devices as Superconductors and the Commercial Generic Bioprocessing Apparatus. These experiments will provide important information to Earthbound scientists.

*Atlantis* and crew spent five days transferring supplies and equipment to Mir. During operations, the first American crew exchange took place

**The Russian Space Station Mir is backdropped over a storm in the Roaring 40s near Heard Island in the south Indian Ocean.**

## Space Shuttle *Atlantis*

September 16-26, 1996

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|---|---|
| **Commander**: | Bill Readdy |
| **Pilot**: | Terry Wilcutt |
| **Mission Specialist**: | Jay Apt<br>Tom Akers<br>Carl Walz |
| To Mir | John Blaha |
| From Mir | Shannon Lucid |

**Astronaut Bill Readdy looks over a checklist at the commander's station on the flight deck.**

as Astronaut John Blaha took his place as part of the Mir 22 crew and began his four month stay on the Russian outpost.

At the completion of the flight President Bill Clinton, speaking at Ellington Field, praised the "incredible skill and stamina" of Astronaut Shannon Lucid after her stay on the Russian Mir Space Station, and said that her achievement is an example to young women across the nation.

"Her achievement is the longest single flight by an American in space and the longest duration for any woman in space," said Clinton who later presented Lucid the Congressional Space medal of Honor at the White House. "Our space pioneers reflect the very best of America's spirit of exploration, our never ending search for new horizons. Dr. Shannon Lucid today stands tall among them all. We are grateful for her. We welcome her home."

## Mission Events

The on-time launch of Space Shuttle *Atlantis* at 3:54 a.m. CDT, September 16, 1996, began a 10 day mission in which the shuttle docked with the Russian Space Station Mir and retrieved U.S. astronaut Shannon Lucid, ending her record-setting six-month stay onboard Mir.

In the days preceding the September 18 docking, the *Atlantis*' crew began packing materials and supplies and filling the first four containers of water to be delivered to the Mir and the setup and activation of the double Spacehab module in the payload bay. One of the experiments activated was the Active Rack Isolation System experiment which is a prototype of an International Space Station (ISS) payload system designed to eliminate vibrations or disturbances caused by crew activity or engine firings.

*Atlantis* docked with the Mir space station at 10:13 p.m. CDT September 19, 1996. After two hours of pressure and leak checks, the hatches between the two spacecraft were opened at 12:40 a.m. CDT, and the two crews greeted one another to begin five days of joint operations. The official time of crew exchange was recorded at 6 a.m. CDT, when Blaha brought a custom-made Soyuz seatliner over to the Mir from *Atlantis* for installation in the Russian capsule.

Soon after the crew members completed their welcoming ceremony, they went to work, hauling bags of water and other supplies from the shuttle's Spacehab module into the Mir. More than 6,000 pounds of equipment and logistical supplies were transferred to the Mir before *Atlantis* undocked from the space outpost.

During docked operations, the shuttle crew activated the Mechanics of Granular Materials experiment which sought to study what happens to granular materials under low stress. This research could lead to improved selection and preparation of building sites in earthquake-prone areas, and in the study of erosion, mining and offshore engineering.

The hatch between the two spacecraft was sealed shut at 7:24 a.m. September 22, and at 8:33 p.m. CDT September 23, the two spacecraft separated. Following a brief one and a half revolution fly around the Mir, the American shuttle headed for home.

*Atlantis* glided to a stop at 7:13 a.m. CDT September 26, 1996.

## Payload Descriptions

**NASA-Mir Experiments**

New technologies and techniques were evaluated using the Mir space station as a test bed.

Earth sciences research in ocean biochemistry, land surface hydrology, meteorology, and atmospheric physics and chemistry also were performed. Observation and documentation of transient natural and human-induced changes was accomplished with the use of passive microwave radiometers, a visible region spectrometer, and hand-held photography. Earth orbit allowed for documentation of atmospheric conditions, ecological and unpredictable events, and seasonal changes over long periods.

Fundamental biology research continued developmental investigations that study the effects of the space environment on the biological systems of plants. Prolonged exposure to microgravity provides an ideal opportunity to determine the role gravity has on cell regulation and how this affects development and growth. Investigations under this discipline also characterized the internal radiation environment of the Mir space station.

Human life sciences research consisted of investigations that focused on the crew member's adaptation to weightlessness in terms of skeletal muscle and bone changes, psychological interactions, immune system function, and metabolism. In addition, environmental factors such as water quality, air quality, surface assessment for microbes, and crew microbiology were assessed.

The ISS risk mitigation discipline consisted of several technology demonstrations associated with human factors and maintenance of crew health and safety aboard the space station. In order to improve the design and operation of the ISS, information was gathered to fully evaluate the Mir interior and exterior environments. This discipline included investigations of radio frequency interference, crew force impacts to structures, particle impact on the station, docked configuration stability, water microbiological monitoring and inventory management.

Microgravity research advanced scientific understanding through studies in biotechnology, fluid physics, combustion science, and materials science. The ambient acceleration and vibration environment of Mir was characterized to support future research programs.

Space science research continued with the externally mounted Mir Sample Return Experiment (MSRE) and Particle Impact Experiment (PIE) payloads. These experiments continued to collect interstellar and interplanetary space particles to further our understanding of the origin and evolution of planetary systems and life on Earth.

**Environmental Radiation Measurements**: Exposure of crew, equipment, and experiments to the ambient space radiation environment in low-Earth orbit poses one of the most significant problems to long-term space habitation. As part of the collaborative NASA/Mir Science program, a series of measurements was compiled on the ionizing radiation levels aboard Mir. During the mission, radiation was measured in six separate locations throughout the Mir using a variety of passive radiation detectors. These measurements yielded detailed information on the effectiveness of spacecraft shielding in the 51.6 degree orbit of the Mir.

**Greenhouse-Integrated Plant Experiments**: The microgravity environment of the Mir space station provided researchers an outstanding opportunity to study the effects of gravity on plants, specifically dwarf wheat. The greenhouse experiment determined the effects of space flight on plant growth, reproduction, metabolism, and production. By studying the chemical, biochemical, and structural changes in plant tissues, researchers hope to understand how processes such as photosynthesis, respiration, transpiration, stomatal conductance, and water use are affected by the space station environment. This study was an important area of research as plants could eventually be a major contributor to life support systems for space flight. Plants produce oxygen and food, while eliminating carbon dioxide and excess humidity from the environment. These functions are vital for sustaining life in a closed environment such as Mir or the ISS.

Wheat was planted and grown in the "Svet," a Russian/Slovakian developed plant growth facility, where photosynthesis, transpiration, and the physiological state of the plants are monitored. The plants were observed daily, and photographs and video images were taken. Samples also were collected at certain developmental stages, fixed or dried, and returned to Earth for analysis.

**Human Life Sciences**: The task of safely keeping men and women in space for long durations, whether they are doing research in Earth orbit or exploring other planets in our solar system, requires continued improvement in our understanding of the effects of space flight factors on the ways humans live and work. The Human Life Sciences (HLS) project had a set of investigations to determine how the body adapted to weightlessness and other space flight factors, including the psychological and microbiological aspects of a confined environment and how they readapt to Earth's gravitational forces. The results of these investigations guide the development of ways to minimize any negative effects so that crew members can remain healthy and efficient during long flights, as well as after their return to Earth.

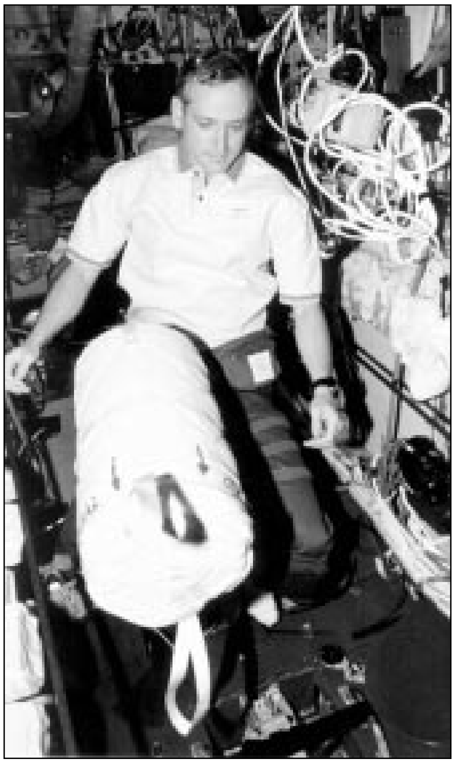
**Assessment of Humoral Immune Function During Long Duration Space Flight**: Experiments concerned with the effects of space flight on the human immune system are important to protect the health of long duration crews. The human immune system involves both humoral (blood-borne) and cell-mediated responses to foreign substances known as antigens. Preflight, a baseline saliva and blood sample were collected. While on Mir, the crew was administered a subcutaneous antigen injection. In flight and post flight, follow-up blood and saliva samples were collected to measure the white blood cell activation response to the antigen.

**Biotechnology System (BTS)**: The Bioreactor rotating wall vessel developed at the Space Cell Biology and Biotechnology Center at NASA's Johnson Space Center was the first of a series of long-duration cell culture experiments. BTS studied the three-dimensional growth of cartilage cells during its 147-day mission. Cartilage is the material that makes up the joints in the human body. The Bioreactor enabled the growth of mature cartilage from a small number of starting cells. This level of maturity is rarely achieved by other culture methods. Dr. Lisa Freed of MIT used BTS to study cartilage so that cartilage cells may be engineered for replacement and transplantation.

**Material in Devices as Superconductors (MIDAS)**: The MIDAS experiment, developed at NASA's Langley Research Center, Hampton, VA, was transferred over to the Russian Mir space station for approximately four months. While on the Mir, MIDAS measured the electrical properties of high temperature superconductor (HTS) materials during extended space flight and compiled the results in a database for commercial use. HTS materials may be used in a variety of device applications to reduce power requirements and thermal losses. In addition to the development of a database, the MIDAS experiment demonstrated a manufacturing process using integrated superconductor and conventional microelectronics. There were no previous flights that characterized HTS material in space flight at cryogenic temperatures. Sample boards were provided by the Eaton Company (USA), the Moscow Institute of Electronic Equipment (Russia), and the Langley Research Center.

**Commercial Generic Bioprocessing Apparatus (CGBA):** Among the experiments carried by the CGBA to Mir were small, self-contained aquatic

**Astronauts Shannon Lucid and John Blaha reunite soon after the Atlantis/Mir docking.**



**Astronaut Tom Akers transfers the Protein Crystal Growth $GN_2$ Dewar experiment onto Mir.**

ecosystems—complete with both plants and animals—developed by Paragon Space Sciences of Tucson, AZ. A leading American pharmaceutical company conducted experiments to determine the secondary metabolite production in plant tissue. In addition, a leading biotechnology concern was taking advantage of this long duration mission to conduct crystallization experiments involving proteins and oligonucleotides.

**STS-79 SCIENCE EXPERIMENTS**

Three experiments made a round-trip voyage aboard *Atlantis* itself: The Extreme Temperature Translation Furnace, the Commercial Protein Crystal Growth experiments and the Mechanics of Granular Materials experiment. An IMAX camera and the Shuttle Amateur Radio Experiment (SAREX) also flew on STS-79

**The Extreme Temperature Translation Furnace (ETTF)**: The ETTF, which was integrated into the SPACEHAB module, was a new furnace design allowing space-based processing up to 900 degrees Centigrade and above. ETTF was developed by McDonnell Douglas Aerospace, Huntsville, AL, and the Consortium for Materials Development in Space at the University of Alabama-Huntsville (UAH), a NASA Commercial Space Center. ETTF was designed to investigate how flaws form in cast and sintered metals. Studying the basic thermodynamics and behavior of pores and metal grains allows metallurgists to make stronger machine tools on Earth. The furnace was integrated into a SPACEHAB single rack to demonstrate the facility's on-orbit capabilities. Teledyne Advanced Materials Systems was a partner for the sintered samples.

**Commercial Protein Crystal Growth (CPCG) Experiments**: STS-79 included the 31st shuttle flight of a Protein Crystal Growth payload managed by the Center for Macromolecular Crystallography, a NASA Commercial Center for the Development of Space based at the University of Alabama at Birmingham. The complement of CPCG experiments aboard this mission was comprised of 128 individual samples involving 12 different proteins. The samples were processed at 22 degrees Centigrade using the newly developed Commercial Vapor Diffusion Apparatus (CVDA). The goal of these experiments was to produce large, well-ordered protein crystals in the microgravity environment from very small volumes of protein solutions.

The samples on this mission included a protein responsible for causing some types of asthma and other allergic reactions. Another was an enzyme that is important for the activation of the "complement system." This system of enzymes protects humans by killing microorganisms and infected cells.

**Mechanics of Granular Materials (MGM)**: The MGM experiment sought to develop a quantitative scientific understanding of the behavior of cohesionless granular materials in dry and saturated states at very low confining pressures and effective stresses. Cohesionless granular materials are unlike other engineering materials since their strength and stiffness properties derive entirely from friction and the change of volume associated with the application of shear stresses. The strength and stiffness of these materials are usually several orders of magnitude lower than cementious composites. Granular material properties depend on confinement. Investigators expected to see higher axial loads for a given axial displacement in microgravity. This data could help scientists to understand the behavior of the Earth's surface during earthquakes and landslides. The MGM experiment was developed by Sandia National Laboratories, in cooperation with the University of Colorado and Marshall Space Flight Center.

**IMAX**: During the STS-79 mission, the crew used an onboard IMAX camera to document activities on Atlantis and Mir. NASA is using the IMAX film medium to document its space activities and better illustrate them for the public. This system, developed by the IMAX Corp., Toronto, Canada, used specially designed motion picture cameras and projectors to record and display high-definition, large screen pictures.

**Shuttle Amateur Radio Experiment (SAREX)**: Ham radio operators and students made radio contact with the orbiting shuttle as part of the Shuttle Amateur Radio Experiment, SAREX. Some of these amateurs volunteered to assist student groups who asked questions of the astronauts during specially scheduled contact times.

**RISK MITIGATION EXPERIMENTS**

Several experiments were planned to reduce the development risk for the International Space Station. These were the Mir Electric Field Characterization, Real-time Radiation Monitoring Device, the Active Rack Isolation System and the Inventory Management System.

**Mir Electric Field Characterization (MEFC)**: The radio frequency interference (RFI) environment around the shuttle is of increasing concern due to new ground-based transmitters for communications and radar applications. In addition, the 52 degree inclination of the ISS orbit will expose it and the shuttle to larger radio-frequency radiation levels due to longer travel over populated areas.

Data from this experiment will assist designers in the selection of frequency bands for radio-frequency components of ISS and its supporting systems.

**Real-time Radiation Monitoring Device (RRMD)**: RRMD measured the elemental composition and energy spectra of cosmic radiation in real-time. It also provided information on the effects of radiation on biological samples. The detector unit contained a Linear Energy Transfer Spectrometer. The investigators were interested in the ability of bacteria to repair any radiation-damaged DNA. RRMD was developed by NASDA and Mitsubishi Heavy Industries, Ltd. of Japan.

**Active Rack Isolation System (ARIS)**: ARIS was designed to isolate certain classes of science experiments from major mechanical disturbances that might be found on the ISS. The objective of the ARIS flight experiment was to isolate the system from accelerations due to the space shuttle and also due to the Shuttle/Mir orbital complex, which provided a low frequency vibration environment similar to that anticipated for the ISS. During the flight, periods without jet firings as well as specific jet firing occasions were required to evaluate ARIS performance. The ARIS rack was developed by the Boeing Defense and Space Group in Seattle, WA.

**Inventory Management System (IMS)**: This experiment sought to determine the utility of using a bar code reader to keep track of items transferred from shuttle to Mir and from Mir to shuttle. Bar code tags were attached to selected transfer items. Results of this experiment will help to determine the type of system required for the ISS. The IMS experiment was developed at the Johnson Space Center.

**CREW BIOGRAPHIES**

**Commander: William F. Readdy (Captain, U.S. Naval Reserve)**. Readdy, 44, was born in Quonset Point, RI, but considers McLean, VA, to be his hometown. He received a bachelor of science degree in aeronautical engineering (with honors) from the U.S. Naval Academy and graduated from the U.S. Naval Test Pilot School.

Readdy was selected as an astronaut by NASA in 1987. In addition to STS-79, he was the pilot of STS-42 in 1992 and STS-51 in 1993. With the completion of STS-79, he has logged more than 672 hours in space.

**Pilot: Terrence W. Wilcutt (Lieutenant Colonel, USMC)**. Wilcutt, 47, was born in Russellville, KY. He received a bachelor of arts degree in math from Western Kentucky University in, and graduated from the U.S. Naval Test Pilot School.

Wilcutt was selected by NASA in January 1990, and was the pilot on Mission STS-68 in 1994. With the completion of STS-79, Wilcutt has logged more than 513 hours in space.

**Mission Specialist: Jay Apt (Ph.D.)**. Apt, 47, was born in Springfield, MA, but considers Pittsburgh, PA, to be his hometown. He received a bachelor of arts degree in physics (magna cum laude) from Harvard College and a doctorate in physics from the Massachusetts Institute of Technology.

Apt was selected as an astronaut candidate in 1985, and served as a mission specialist on three previous flights—STS-37 in 1991, STS-47 in 1992 and STS-59 in 1994. With the completion of STS-79, Apt has logged more than 847 hours in space, including 10 hours and 49 minutes on two space walks.

**Mission Specialist: Tom Akers (Lieutenant Colonel, USAF)**. Akers, 45, was born in St. Louis, MO, but was raised and educated in his hometown of Eminence, MO. He received bachelor and master of science degrees in applied mathematics from the University of Missouri-Rolla and graduated from the U.S. Air Force Test Pilot School in Class 82B.

Akers was selected for the astronaut program in 1987. He had previously flown on STS-41 in 1990, STS-49 in 1992, and STS-61 in 1993, With the completion of STS-79, Akers has accumulated more than 814 hours of space flight.

**Mission Specialist: Carl E. Walz (Lieutenant Colonel, USAF).** Walz, 41, was born in Cleveland, OH. He received a bachelor of science degree in physics from Kent State University, OH, and a master of science in solid state physics from John Carroll University, OH. He graduated from the U.S. Air Force Test Pilot School in Class 83A.

Walz was selected to be an astronaut in 1990 and was a veteran of two space flights, STS-51 in

**Crew in-flight, on Mir. Front row, left to right, Alexander Y. Kaleri, Jerome (Jay) Apt, John E. Blaha, William F. Readdy and Shannon Lucid. Back row, Thomas D. Akers, Carl E. Walz, Valeri G. Korzun and Terrence W. Wilcutt.**

# STS-79
## Quick Look

Launch Date: September 16, 1996
Time: 3:54 a.m. CDT
Site: KSC Pad 39A

Orbiter: *Atlantis*
OV-104—17th flight

Orbit/In.: 160 naut. miles
51.6 degrees

Mission Duration: 10 days, 3 hrs, 18 mns.

Landing Date: September 26, 1996
Time: 7:13 a.m. CDT
Site: Kennedy Space Center

Crew: Bill Readdy, (CDR)
Terry Wilcutt, (PLT)
Jay Apt, (MS1)
Tom Akers, (MS2)
Carl Walz, (MS3)
John Blaha, (MS4 launch-dock)
Shannon Lucid, (MS4 dock-landing)

Cargo Bay Payloads: Orbiter Docking System
SPACEHAB Double Module

In-Cabin Payloads: IMAX
Risk Mitigation Exp.
SAREX
Middeck Science Hardware

September 1993 and STS-65 in July 1994. With the completion of STS-79, Walz has accumulated more than 833 hours in space.

**Mission Specialist: John E. Blaha (Colonel, USAF, Ret.)**. Blaha served as a Mission Specialist from launch through docking with the Mir space station. After docking, a crew exchange occurred and Blaha officially became a member of the Mir 22 crew.

Blaha, 54, was born in San Antonio, TX. He received a bachelor of science in engineering from the United States Air Force Academy and a master of science in astronomical engineering from Purdue University, and graduated from the U.S. Air Force Aerospace Research Pilot School.

Blaha was selected as an astronaut in May 1980. He had four previous space missions serving as commander on two flights—STS-58 in 1993 and STS-43 in 1991 and as pilot on two flights—STS-33 and STS-29, both in 1989. At the completion of STS-79, Blaha had logged more than 1035 hours in space.

**Mission Specialist: Shannon W. Lucid (Ph.D.)**. Lucid was the second NASA astronaut to serve as a researcher aboard the Mir station. She had been aboard the orbiting facility since Atlantis undocked during STS-76 in March 1996. On September 7, 1996, Lucid reached her 169th day in space, thus surpassing Elena Kondakova for the record of most time in space by any woman on a single flight. After the crew exchange with Blaha was completed, Lucid served as mission specialist for the remainder of the STS-79 flight.

Lucid, 53, was born in Shanghai, China, but considers Bethany, OK, to be her hometown. She received a bachelor of science degree in chemistry, and a master of science and doctor of philosophy degrees in biochemistry from the University of Oklahoma.

Lucid was selected by NASA in January 1978 and became an astronaut in August 1979. Prior to STS-79, she served as a mission specialist on four space shuttle missions—STS-51G in 1985, STS-34 in 1989, STS-43 in 1991 and STS-58 in 1993. With the completion of STS-79 she had logged more than 5354 hours in space.


**STS-79 was the fourth in a series of NASA docking missions to the Russian Mir Space Station, leading up to the construction and operation of the International Space Station (ISS). As the first flight of the Spacehab Double Module, STS-79 encompasses research, test, and evaluation of ISS, as well as logistics resupply for the Mir Space Station.**

**STS-79 is also the first NASA-Mir American crew member exchange mission, with John Blaha replacing Shannon Lucid aboard the Mir Space Station. The lettering of their names either up or down denotes transport up to the Mir Station or return to Earth on STS-79.**

**The STS-79 patch is in the shape of the Space Shuttle's airlock hatch, symbolizing the gateway to international cooperation in space. The patch illustrates the historic cooperation between the United States and Russia in space. With the flags of Russia and the United States as a backdrop, the handshake of EVA-suited crew members symbolizes mission teamwork, not only of the crew members but also the teamwork between both countries' space personnel in science, engineering, medicine, and logistics.**